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ABSTRACT

This study examined the transition from concrete to formal operations in very bright children in an effort to determine whether high ability in concrete operations would carry over into formal operational ability, and also to investigate precocity in regard to formal operations. Subjects were 38 white middle-class children ranging in age from approximately 8 to 14 years. Of these, 25 were younger students (approximate ages 8 to 12) with IQ's greater than 160, and 13 were older (approximate ages 12 1/2 to 14) with IQ's in the range of 150. The children were tested individually in their homes on three formal operational tasks adopted from Inhelder and Piaget as well as two moral reasoning dilemmas from Adelson and Piaget. The formal operational tasks were: communicating vessels, oscillation in a pendulum, and a balance problem. Tasks are described. Scoring was adopted from Inhelder and Piaget. Two judges assigned one of four categorical ratings, two concrete and two formal, to each task. Results indicate that high ability in children over the age of 11 does carry over into formal operations; but that bright children under 11 years demonstrate a low rate of precocity in formal operational ability, with exception of the pendulum problem. These results and responses to the moral questions are discussed. (Author/SB)

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Formal operations in very bright 8- to 14-year olds

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In a paper that appeared in a recent edition of Human Development, Webb (1974) reported a series of studies on concrete and formal operational behavior in a group of very bright youngsters. The group ranged in age form 6 to 11 years and was selected on the basis of a tested IQ in excess of 160. The results of those studies can be easily summarized: The bright youngsters, including those who were only 6 and 7 years old, were capable of solving the most difficult concrete operational problems with aplomb; but only a small fraction of the oldest children in the group, all 10 years, 6 months and older, seemed to be at all competent with the formal operational problems. If we take Inhelder and Piaget's original age estimates as correct and assume that formal operational performance begins at age 11, it is clear that there is no substantial precocity in the onset of formal operations in this group of bright children; there is, on the other hand, considerable precocity within the stage of concrete operations associated with high IQ. Horizontal décalage is, in effect, reduced to zero.

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If these findings prove to be generally true, they suggest a two-factored relationship between Piagetian and psychometric notions of intelligence. The transition from one major stage to the next is apparently constrained by maturational factors that are independent of psychometric intelligence. Once a child makes the transition from one stage to the next, however, how quickly he masters all the problems that are exemplars of that stage is readily predicted from his IQ.

Our first study seemed to establish that very young, bright children could solve difficult concrete operational problems. Whether these subjects would go on to start solving the formal problems at age 11 and do them very well thereafter remained to be seen. Also, to make a strong claim that there is no precocity in formal operations as a function of high IQ requires a more extensive sampling of problems. Therefore, we extended our study using older, bright subjects and additional formal operational problems.

Method

Subjects: Thirty-eight white middle-class children ranging in age from 8;3 (8 years, 3 months) to 14;4 were studied. Twenty-five younger students (8;3 - 12;2) with IQ's greater than 160 were located through a program operated by the Anne Arundel County, Maryland school system. IQ's were determined by the Slosson Intelligence Test which correlates above .9 with the Stanford-Binet. Seven girls and 18 boys were included in this sample.

Thirteen older students ranging in age from 12;7 to 14;4 were selected from a Verbal Talent Search conducted at the Johns Hopkins University. Seven boys and six girls in this group scored from 490 through 670 on the verbal portion of the Scholastic Aptitude Test: the mean SAT-V score for these subjects was 558. We estimate that these scores put the youngsters in roughly the upper tenth of the top percentile of the age group - a score that would suggest an IQ in the 150 range.

Procedure: Children were tested individually in their homes by the experimenter and an assistant during a single five-week period during summer, 1974. Three formal operational tasks adopted from Inhelder and Piaget (1958) were used as well as two moral reasoning dilemmas adopted from Adelson, et al., 1969, and Piaget, 1965. The formal operational tasks were communicating vessels, oscillation in a pendulum, and the balance problem.

1. Communicating Vessels. Subjects were asked to make predictions as to where the water level would be in a thin column connected to a wide column by rubber tubing if water were poured into the wide column up to a certain level. Subjects were them asked to predict whether or not the thin column could be filled to the top, the level of which was approximately 12 inches above the brim of the wide column. The next question was, "If I move the wide column up and down, what will happen to the water level in the thin column?" After this prediction subjects were encouraged to experiment with the apparatus. The child was asked for a general rule as to "how the water level in one column relates to the water level in the other column."

Finally, subjects were asked to explain why water seeks its own level if they indeed arrived at that generalization.

2. Oscillation in a Pendulum. Subjects were asked to discover what determines the period of a pendulum. The apparatus consisted of a wooden dowl supported by two metal stands from which were suspended two short, medium and long strings and a set of metal washer weights. The experimenter demonstrated the problem and explained the concept of the period of the pendulum as well as the factors that might affect it. At this point the subject was invited to experiment and discover the factor or factors that determine the period. This task challenged the subject to eliminate the distractor variables of height of drop, weight of object, and force of drop in order to isolate the controlling variable of length of the string.

3. Balance Problem. The apparatus consisted of a blance constructed from an 18 inch wooden ruler mounted on a frame with holes at each inch mark, and a set of metal washer weights. The child was asked to balance a number of specific combinations of weights and distances sometimes using more than one solution. Subjects were then asked to formulate the general rule for balancing the moments of force. Care was taken to distinguish between empirical strategies and the theoretical rule that was sought.

Scoring: Transcripts of audio tapes made during each testing session served as protocols for scoring. Each protocol was scored independently by two judges. The scoring system was adopted from Inhelder and Piaget (1958) and corresponds to that used by Keating (1973).

One of four categorical ratings, two concrete (IIA and IIB) and two formal (IIIA and IIIB) operational were assigned to each task. A breakdown of the ratings for each of the three tasks follows.

For the communicating vessels problem a IIA response meant the subject was aware of the elevation relation between the two water levels; a IIB rating meant the subject observed the equality of water levels but was unable to explain the phenomenon. Preliminary explanation and the beginnings of formal structuring rated a IIIA score. Finally, a IIIB rating was contingent upon the subject's explaining the final equality of water levels due to an equilibriation of pressures despite unequal volumes.

The pendulum problem determined whether or not the subject could experiment by holding extraneous factors constant while looking at the effect of one variable. A concrete operational response (IIA) was based upon the child's inability to separate variables and to order accurately the effects of one variable such as weight. At the more advanced IIB concrete operational stage a child still varied several conditions simultaneously but accurately ordered the effects of confounding variables. Responses involving preliminary separation of variables rated a IIIA score; spontaneous and anticipatory separation of variables received a clear-cut formal operational (IIIB) rating.

For the balance problem a IIA response meant the subject solved the combinations of weights and distances through a random trial and error procedure.

The more advanced concrete operational stage (IIB) was characterized by a systematic trial and error procedure in which the subject discovered the inverse correspondence of weights and distance. Preliminary explenation of the proportionality between weight and distance received a IIIA rating. Finally, an explanation of the balance rule as well as vorrect anticipatory responses to new balance situations was scored as IIIB.

Results

Before discussing the results, I want to point out that the data to be discussed below are derived from ratings of transcribed protocols and there are more reliability problems than working from direct observations. When the entire four point scale was used, we found perfect agreement between judges on only about 60 to 65 percent of the cases. None of the disagreements, however, are of more than one interval. If only a two point scale is considered, judgement of IIA or IIB versus IIIA or IIIB agree in about 85 percent of the cases (.82 to .88). Thus, the inter-tater agreement for concrete versus formal operations is less than perfect, but probably in an acceptable range. We are currently working to see whether we can make the substage distinctions made by Inhelder and Piaget with an acceptable degree of reliability. In the presentation to follow, I will be concerned primarily with distinctions between concrete and formal operational performance. Distinctions between substages must be viewed with some caution.

While there are other ways of presenting the findings, my major concern here is with the question of precocity or the lack of it before and after the age of 11. Granted that it is somewhat foolish to expect a magic transformation at the 11th birthday, I am going to proceed on that basis. We had a total of 21 subjects below the age of 11;0 in our sample. The majority of these (12) were rated at a formal level on the pendulum problem, though only one of these was the fully formal IIIB level. This finding was a clear contradiction to our expectations from the previous work and will require further comment. For the moment, however, I will concentrate on the performance of subjects under the age of 11;0 on the other two problems.

With 21 subjects under the age of 11;0 and - exculding the pendulum problem - two problems per subject, we had a total of 42 ratings. Of these, eight were at the formal level with none at the IIB or fully formal level. Of the eight, three were generated by two boys, 10;11. The remaining five were produced by three younger boys. Two boys (10;4 and 10;6) were rated at the formal level on both problems as well as on the pendulum problem. A third boy only 9;8 was rated at a formal level on the communicating vessels problem. I was not one of the original judges of these protocols, but have studied these particular subjects closely. For the two 10-year-olds, there was some question about the rating, in my opinion, on one or the other of the problems, but I believe that both were operating at a marginally formal level on both problems. The youngest subject was clearly at a formal level on the communicating vessels as well as on the pendulum problems, but clearly was not on the balance problem.

This young subject got the only IIIB rating given to a subject below the age of 11 with his response to the pendulum problem, but could not deal with the notion of proportionality on the balance problem at all. These three subjects constituted the only reasonably clear cases of precocity below the age of 11. Each was either marginal or mixed in his formal operational performance, but formal to some degree.

In the 17 subjects 11;0 and older, performance on all problems is overwhelmingly formal. On all three problems for the 17 subjects, there was a total of 11 ratings at the concrete level. Five of these were generated by three subjects who were within a few months of their 11th birthday. The other systematic departure from the formal operational level was that 4 of the 7 girls above the age of 12;0 were at a concrete level on the balance problem. With these exceptions, concrete ratings are scattered among the older subjects and come only one to a subject.

Discussion

I proposed two hypotheses at the beginning of this paper: (1) that intellectual precocity defined psychometrically by very high (greater than 160) IQ does not imply precocity <u>across</u> Piagetian stages, and (2) that very bright 11- to 14-year olds would demonstrate <u>within</u> stage precocity by successfully completing a series of formal operational tasks. Data from the present study for the most part support these hypotheses.

Results from both the communicating vessels task and the balance problem support the hypotheses that very bright, young

under the age of 11 demonstrate a low rate of precocity in formal operations. These findings replicate Webb's (1974) observation that children ranging in age from 6 to 11 years revealed essentially no precocity in formal operational ability.

The one clear exception to our predictions were the data from the pendulum problem. It is possible that there is some degree of horizontal décalage among formal operational problems and the pendulum problem is quite a simple problem compared to why water levels stay the same or to explaining how a balance works. Inhelder and Piaget's original analysis would support such a contention since they claim the pendulum problem only requires a single formal operation (exclusion) while the other two problems require operations on a formal system. We must note, however, that we did not find similar precocity on the floating bodies problem in our previous work, and we should have by a simple extension of the Inhelder and Piaget argument. A second possibility is that some of our subjects have received some training in experimental methods in a special enrichment program. Since the pendulum problem is the most straightforward application of the classic experimental method of manipulating one variable at a time, the success of our sample may represent the effects of training The final possibility - and the one I personally favor - is that either the method of testing or the scoring system is too lax. Regardless of how this discrepancy is eventually to be explained it is clear that the pendulum problem stands out as an exception to the general pattern of results.

The second part of our hypothesis can be supported without qualification. Our bright subjects over the age of 11 are very good at formal operational problems. Our findings on this point replicate in a more extreme fashion the findings of Keating (1975) on accelerated formal operational performance in bright 11-year-olds. By the time they are 13 or 14, our youngsters are almost certainly better than the average adult population in this country.

Whether our bright subjects will continue to show accelerated growth in their intellectual processed remains to be seen. As I mentioned above, we have begun to question our subjects on social and moral dilemmas for which there is no right answer. Adelson's work on notions of law among adolescents may be considered a prototype for what we wish to accomplish with our gifted sample. Adelson finds an apparent critical period for what we might call a pragmatic orientation toward the law at around 15 years of age and finds, furthermore, that it is relatively independent of intelligence. The results we have obtained to date with our brighter subjects are mixed. Some of our samples appear more spohisticated on social questions than we would expect from Adelson's work, but others have the moral insights of concentration camp guards. The relationship of wisdom to intelligence - whether we define intelligence psychometrically or in Piagetian terms - seems to be another question.

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